Journal of Robotics and Control (JRC)
Volume 2, Issue 5, September 2021
ISSN: 2715-5072 DOI: 10.18196/jrc.25118

Automatic Voltage Regulator as a Voltage Control in 1 Phase Axial Generator System

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***Abstract*—A constant output voltage on a generator is very important to produce the expected power supply. Changes in the output voltage of a generator are influenced by various disturbing factors, one of which is load and Rotations Per Minute (RPM) which are not always constant. Therefore, we need a special regulator equipment to keep the generator output voltage constant. The problem of voltage instability during load changes must be overcome to keep the voltage constant, so that equipment is needed that can control the voltage stability. This tool is the Automatic Voltage Regulator (AVR). The purpose of this study is to design a voltage control device in a single-phase axial generator system. The research method used consists of 3 stages, namely: 1). Design and design of tools, 2). Stages of making tools, 3). Stages of testing the tool. The results of the research were obtained when an axial generator with an inner air gap of 0.4 cm, outer 0.5 cm and rpm 2589. The output voltage of the generator began to decrease significantly until it reached -70 volts and rpm also decreased to -200. In contrast, when the generator is operated using the AVR, the reduction only reaches -30 volts. However, when the generator is operated with AVR, the decrease in rpm is greater until it reaches -220**.

***Keywords*—Automatic Voltage Regulator, voltage, axial generato, rotor**

I. INTRODUCTION

Generators that are often found in the market are high-speed induction generators, in this type of generators require high rotation and initial electrical energy to create the magnetic field [1][2][3][4]. As the radial type generator, the torus model is one type of generator that operates at speeds above 1500 rpm which uses the Internal Combustion Engine (ICE) such power as the main propulsion diesel generator rotor [5][6][7].

Low-speed generators that are widely used are axial flux type generators [8][9][10]. Axial flux generators are very efficient to use because they can work well at low rotational speeds [11]. Ease of manufacture and scale-up of a permanent magnet generator become a consideration in designing the generator with a capacity of certain power, a certain tension and a pace of work specified only by changing parameters such as the strength of the magnetic flux, number of reels and coils, and also the number of magnets and wire diameter sizes [12][13]. Generator flux axial type rotor double stator single is one of the developments of the axial flux generator [14][15].

A constant output voltage in the generator is very important to produce the expected power supply [16][17][18][19]. Changes in the output voltage of a generator are influenced by a variety of confounding factors, one of that is the loads and Rotations Per Minute (RPM) which are not always constant [20].

Then the parameters of the plant, there must be a tool that can be regulated so that the plant continues to operate well by continuing to supply loads in safe and stable conditions. Nowadays, there is equipment that can set the parameters of the generator and work automatically. One type of quipment is the Automatic Voltage Regulator (AVR) in such a way as to be able to regulate the value of the voltage generated by a generator.

II. LITERATURE REVIEW

The axial generator is one type of electric engine that can generate electrical energy with the direction of the flux flow perpendicularly [21][22]. This type of generator continues to be developed with a variety of design variations to obtain a high level of efficiency to be implemented with existing natural resources. Generator flux axial type rotor double stator single without iron core is one of the developments of axial flux generator [23][24][25][26]. This generator is usually used for the generation of electrical energy at low rotations. This generator uses a double rotor flanking the stator in the middle. The stator part is a coil without an iron core while the rotor part consists of several pairs of a permanent magnet that function as the main field generator. The greater the surface area of the permanent magnets are used, the more the magnetic flux is generated by the magnet permanent and penetrate the coil on the stator so that the induced electromotive force (GGL) is also getting higher.

A. The Working Principle of Axial Generator

Based on the law of faraday, if a reel or coil of wire and then there is a magnet that is moved or vice versa, a magnetic flux will arise which flows on the coil caused by induced GGL, the flow of magnetic flux that flows in the coil called as the current flow, while the induced GGL changes at the lowers of the coil as a potential or voltage difference. Based on the electromotive force or voltage that causes an electric current proportional to the rate of change of magnetic flux through the coil. If written mathematically is as follows:

$$Ei = -N \times \frac{\Delta\theta}{\Delta t} \quad (1)$$

Where:

Ei = Induction

N = Tum (Weber)

$\Delta\theta$ = Magnetic flux (Wb)

Δt = Time change (second)

B. Axial Generator Design

The power supply circuit is used to supply direct current /voltage for electronic devices that require DC supply. Electronic devices that require power supplies are Arduino, drive relays. The required voltage is 12Vdc, but the recommended one is 7-12Vdc, so a power supply/adapter with an output of 12Vdc is used.

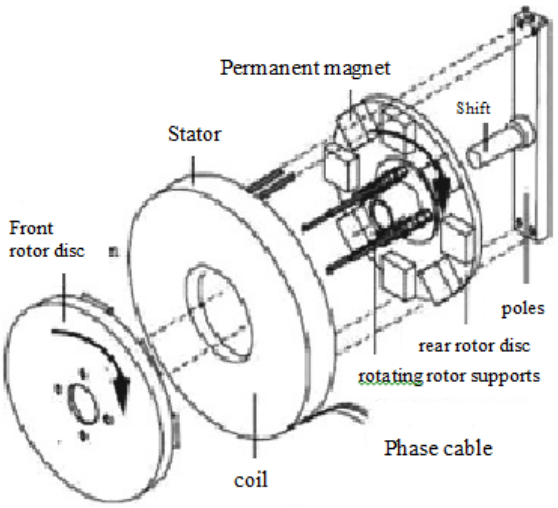

Fig. 1. Axial generator.

In general, the overall design of the generator (Figure 1) has several important parts including the following:

1. Rotor

The rotor (Figure 2) is a part of a rotating generator consisting of a circular arrangement of permanent magnets with different sides (N, S, N, S). For the design of the rotor on a 1 phase generator, the number of magnets used amounts to 2 of many coils that will be used. The number of magnets to be used is 16 for each rotor.

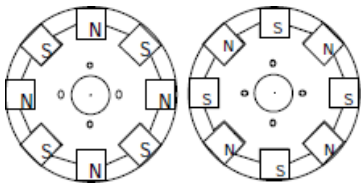

Fig. 2. Rotor design

2. Stator

Stator (Figure 3) is the part that does not rotate (static), in the stator generator there are conductor turns arranged under the rules of both the number of turns, the distance between the windings (pitch factor) and the angular difference between phases, to produce voltage phase 3 which has an angle of 120 degrees to other phases. The ability and quality of the generator are also determined by the copper material that used and the level of insulation resistance to heat through it. On this stator, there are 9 coils with 220 turns per coil and a large diameter wire of 0.70 mm.

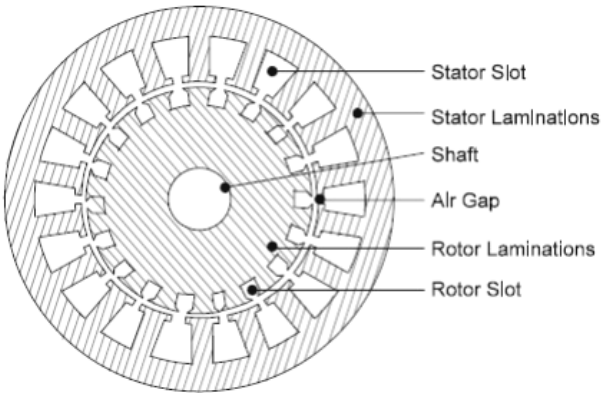

Fig. 3. Stator design

C. Air Gap

The reduction of the total air gap (Figure 4) can be achieved by minimizing the thickness of the resin layer over the magnet and the stator, to produce a higher induction voltage and a higher power output.

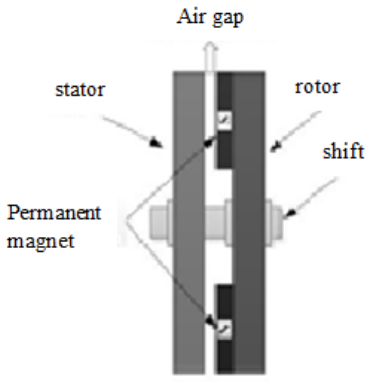

Fig. 4. Axial air gap generator

D. Automatic Voltage Regulator (AVR)

Automatic voltage regulator (AVR) is a device mounted on a generator that can work automatically regulating the voltage or amplitude of the waves generated by the generator to keep stable. AVR works in regulating the output voltage of the generator by controlling the gain of current from the generator. The automatic voltage regulator system diagram is shown in Figure 5.

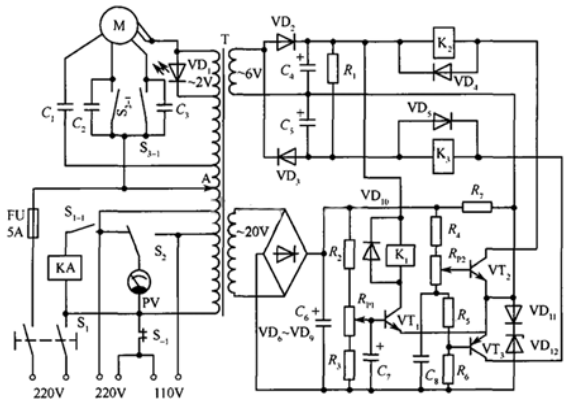

Fig. 5. AVR system diagram.

The main component is the mechanism of tap changing and its control. Each AVR is usually equipped with equipment that can control tap changes automatically based on the incoming voltage even though at that time the AVR is in a state of burden. To determine a single-phase regulator rating can be determined using the following equation:

1. AVR Function
   1. Maintain the stability of the output voltage of the generator;
   2. Arrange the division of pseudo-directive power when working in parallel;
   3. Provide regulating the flow of excitation in conditions of interference so as not to come out of synchronization;
   4. Lowering the voltage quickly when the generator regardless of the load which would conduce over-voltage happened.

2. AVR Working Principle

If the output voltage of the generator below the normal voltage generator voltage, the AVR will increase the flow of reinforcement (excitation) on the exciter. Thus, if there is a change in the output voltage of the generator will be automatically stabilized by the AVR because it is equipped with equipment such as tools used for minimum or maximum restrictions that work automatically. Three AVR states, namely:

1. If the output voltage is high, the AVR error signal (+) will give commands to reduce the excitation current.
2. If the voltage matches the setpoint value (0) then the AVR will not give any orders.

If the output voltage is low then the error signal will (-) then the AVR will give the command to add the excitation current.

III. RESEARCH METHOD

A. Fishbone Diagram

Fishbone diagram is shown in Figure 6. There is some part such as axial generator, electrical part, tools and material.

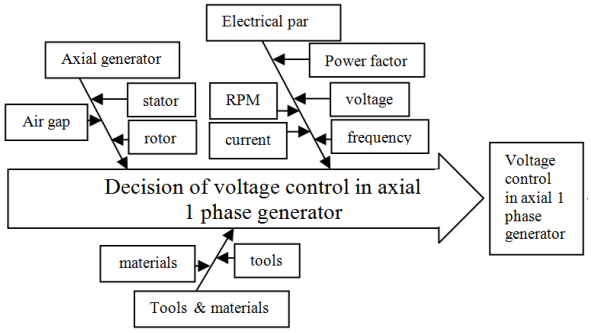

Fig 6. Fishbone diagram

B. Data Collection Method

Water flow velocity data retrieval and power calculation are available to determine the potential used to turn the Archimedes turbine and the turbine will rotate the axial generator and discharge output electrical energy of generator can be raised with a step-up regulator to use 220 volts voltage, then stabilize the voltage using AVR. Like the picture in Figure 7.

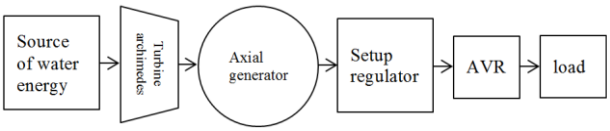

Fig 7. Block diagram.

IV. DATA AND ANALYSIS

A. Automatic Voltage Regulator (AVR) Scheme

The automatic voltage regulator (AVR) circuit schematic is shown in Figure 8.

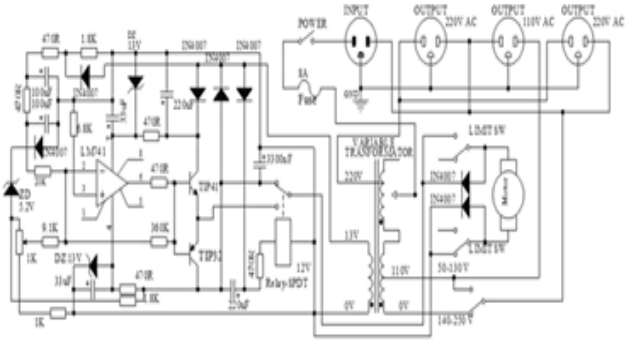

Fig. 8. Automatic Voltage Regulator (AVR) Circuit Scheme.

B. AVR 1000VA Works

In the on state, AVR always adjusts the output voltage automatically with changes in input electric voltage. If the input voltage is less than 220 volts, the AVR strengthens Step Up. Vice Versa, if the input voltage is more than 220 volts, the AVR reduces Step Down. When the AVR is turned off when the utility voltages are less than 220 volts, the AVR ready to use in the next use in the Step-Up position. If when the AVR has turned on again, the electric voltage is more than 220 volts. Then the AVR Output will come out very high

voltage. Even though the incident was only for a moment because the AVR will immediately make adjustments but it is quite dangerous for electronic devices connected to the AVR.

C. Analysis

1. Measurement of the axial generator with an inner air gap 0.7 cm and outer 0.6 cm.

a. Measurement without using AVR on the axial generator using inner air gap 0.7 cm and outer 0.6 cm.

In this trial phase, the axial generator is given an initial rpm of 2580 with an inner air gap of 0.7 cm and an outer 0.6 cm. Furthermore, the generator is given a gradual increase in load to produce the data tests without using AVR in Table 1 and Figure 9.

TABLE I. DATA TEST WITHOUT USING AVR

Rotation (rpm)	Axial Generator (Volt)	Trafo (Volt)	Current (Ampere)	Load (Watt)
2580	26.7	206	0.00	0
2550	20.3	157	0.05	15
2540	14.4	111	0.09	30
2470	10.4	079	0.11	45
2450	07.8	058	0.12	60

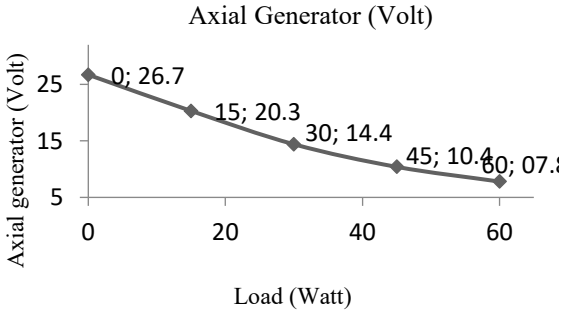

Fig. 9. Axial generator load voltage graph.

When the generator is operated without AVR and given a gradual increase in load starting from 15 watts to 60 watts with 0.7 cm inner air gap, outer 0.6 cm, and 2580 rpm. When the load is above 15 watts and has reached 60 watts then the output voltage regulator began to decrease significantly until it reaches -40 volts and the rpm also decreased to -100.

b. Testing using AVR in axial generator with *inner air gap* 0.7 cm and *outer* 0.6 cm.

In this test phase, the generator is given an initial rpm of 2580 with an inner air gap of 0.7 cm and an outer 0.6 cm. Furthermore, the generator is given a gradual increase in load to produce data tests using AVR in Table II.

When the generator is operated using AVR and given a gradual increase in load starting from 15 watts to 60 watts with an inner air gap 0.7 cm, an outer 0.6 cm, and rpm of 2580. When the load is above 15 watts and has reached 60 watts, the output voltage started to decrease but it is not as high as when the generator is operated without using AVR. The decreasing of the Output voltage generator just reaches -30 volt. In contrast to when the generator is operated without using AVR, the decrease reaches to -40 volts. However, when the generator is operated using AVR the decrease in rpm is greater to -200. This is due to the strengthening of the generator field current carried out by the AVR so that the output voltage remains closer to the set point. So, the generator rotation becomes heavier.

TABEL II. TEST DATA USING AVR

Rotation (rpm)	Axial Generator (Volt)	Trafo (Volt)	Output AVR (Volt)	Current (Ampere)	Load (Watt)
2580	24.0	185	220	0.00	0
2480	11.6	087	144	0.05	15
2360	06.3	046	076	0.07	30
2370	11.7	088	076	0.11	45
2441	09.1	067	061	0.12	60

2. Testing of the axial generator with inner air gap 0.4 cm and outer 0.5 cm

a. Testing without using AVR in Axial generator with inner air gap 0.4 cm and outer 0.5 cm.

In this trial phase, the axial generator is given an initial rpm of 2589 with an inner air gap 0.4 cm and an outer 0.5 cm. Furthermore, the generator is given a gradual increase in load to produce data tests using AVR in Table III as following.

TABEL III. DATA TEST WITHOUT USING AVR

Rotation (rpm)	Axial Generator (Volt)	Trafo (Volt)	Current (Ampere)	Load (Watt)
2589	45.9	354	0.00	0
2368	34.2	263	0.07	15
2150	24.7	185	0.12	30
1798	17.3	135	0.15	45
1582	12.5	091	0.16	60

When the generator is operated without AVR and given a gradual increase in load from 15 watts to 60 watts with inner air gap 0.4 cm, an outer 0.5 cm and rpm of 2589. When the load is above 15 watts and has reached 60 watts so that the output voltage generator began to decrease significantly until it reaches -70 volts and the rpm also decreased to 200.

b. Testing using AVR in axial generator with inner air gap 0.4 cm and an outer 0.5 cm.

In this trial phase, the generator is given an initial rpm of 2540 with an inner air gap 0.4 cm and an outer 0.5 cm. Furthermore, the generator is given a gradual increase in load to produce data tests using AVR in Table IV and Figure 10.

When the generator is operated with using AVR and given a gradual increase in load from 15 watts to 60 watts with inner air gap 0.4 cm, outer 0.5 cm, and rpm of 2540. When the load is above 15 watts and has reached 60 watts so that the output voltage begins to decrease but not as high as when the generator is operated without AVR. The decrease in the output voltage generator just reaches -70 volts. In contrast to when the generator is operated using AVR the decrease up to

-3- volt. But when the generator is operated with AVR the decrease of rpm is greater until reaches -220. This is due to the strengthening of the generator field current carried out by the AVR so that the output voltage remains closer to the set point. So, the generator rotation becomes heavier.

TABEL IV. DATA TEST USING AVR

Rotation (rpm)	Axial Generator (Volt)	Trafo (Volt)	Output AVR (Volt)	Current (Ampere)	Load (Watt)
2540	42.3	328	296	0.00	0
2355	33.2	255	230	0.06	15
1699	11.3	078	126	0.10	30
1188	11.1	088	081	0.11	45
1173	10.3	075	068	0.13	60

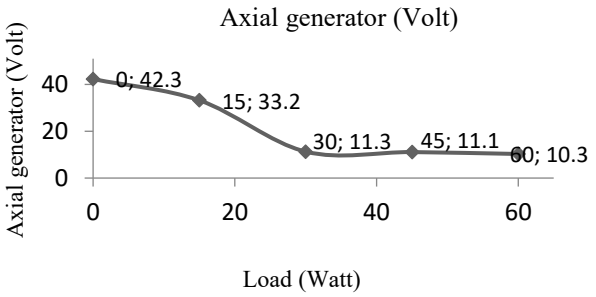

Fig. 10. Axial generator load voltage graph.

The use of AVR in a 1 phase axial generator makes the output voltage of the generator stable as long as it is not overloaded. So that the excitation voltage can meet the needs of the generator when the generator is receiving a large load, it needs a sufficient rpm so that the AVR can still control the generator so that the output voltage matches the desired set point. If the generator excitation voltage is sufficient, even though the generator is given a load of up to 60 watts, the output voltage of the generator will remain stable according to the desired set point.

If the load on the generator increases, it will be increased by the AVR so that the generator output voltage does not go down. Vice versa if the load in the generator is reduced it will be reduced by the AVR so that the generator output voltage does not exceed the desired set point. Because basically, the working principle of AVR is to control the generator voltage supplied from the excitation so that if the input from the excitation unit is less than the generator needs, the generator output voltage will decrease because the AVR is not equipped with an inverter circuit that can increase the voltage. If the excitation voltage value exceeds the needs of the generator, the AVR will reduce the excitation voltage. Automatically so that the generator output voltage does not exceed the specified setpoint.

CONCLUSION

Inner air gap distance of 0.4cm and outer 0.5cm affect the rpm and unstable voltage. The effect of the use of AVR through the increase in load in the generator compared to the generator that does not use AVR is that the generator is operated using AVR the output voltage will be stable according to the desired setpoint as long as the excitation voltage.

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